REMARKS

Claims 6-26 remain in the application.

The Examiner has objected to the drawings for non-correspondence to the text. The amendments to the text on pages 18 and 19 should remove the objections, and no drawing changes are believed to be necessary. The Examiner further objects to the drawings because reference characters 232 and 234, presumably in FIG. 1, are not mentioned in the text. The Examiner's attention is drawn to the passage at page 30, lines 2, 3. Again, no drawing change is believed to be necessary.

The Examiner desired updating of the status of two applications. The amendments to page 1 provide the desired information.

The Examiner has rejected Claims 6-10 and 12 under 35 USC §112, ¶2 for indefiniteness on two grounds. Claim 6 has been amended to provide proper antecedent basis on this ground and another ground. The objection to "rapid thermal anneal" in Claim 12 is believed unnecessary since this term or the related one of rapid thermal processing (RTP) is well established in the semiconductor processing art and is thus definite. However, to avoid any contention on this issue, the passage has been amended to conform with the description of this process at page 33, lines 7, 8. Neither of these amendments are believed to affect the scope of the claims.

The Examiner has rejected Claims 11, 12, and 14 under 35 USC §103(a) as being obviuos over US Patent 5,833,817 to Tsai in view of Musil et al. ("Unbalanced Magnetrons ...", hereafter Musil) and US Patent 5,556,519 to Teer. Claim 11 has been amended to require that the unbalanced magnetron be rotated about the center of the target. Musil is the only applied reference showing an unbalanced magnetron, and his magnetron is large and stationary. Musil does not address sputtering into the high aspect-ratio holes of Tsai and there is no suggestion for applying his unbalanced magnetron to this task.

The Examiner has rejected Claim 13 under 35 USC §103(a) as being obvious over Tsai in view of Musil and Teer and further in view of US Patent 5,599,739 to Merchant. This claim depends upon a claim believed to be in allowable form and should therefore also be allowable.

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The Examiner has rejected Claim 15 under 35 USC §103(a) as being obvious over Tsai in view of Musil and Teer and further in view of US Patent 4,717,462 to Homma. This claim depends from a claim believed to be in allowable form. Further, the art is relatively silent on the use of sputtering to fill tungsten into the high-aspect ratio holes of the sort considered by Tsai. Homma's detailed description is directed to aluminum sputtering and to a particular type of sputter reactor significantly different from that of Tsai. His generalizing statements about the broad range of materials that can be sputtered do not address the difficulties of filling tungsten. Accordingly, a clear suggestion is lacking for the advantages of applying Homma's tungsten sputtering to the challenging geometries of Tsai's.

The Examiner has rejected Claim 16 under 35 USC §103(a) as being obvious over Tsai in view of Musil and Teer and further in view of US Patent 5,593,551 to Lai. Lai, as well as many other practitioners of the prior art, rotate a heart-shaped, presumably balanced, magnetron about the back of the target. Lai's magnetron is effective because of the short separation between its north and south poles, which inherently provides non-uniform sputtering over the much larger surface of the target. Musil's unbalanced magnetron is large, stationary, and apparently provides satisfactory uniformity. It appears to have a circularly symmetric shape about the target center such that rotating it would have no clearly beneficial effect. There is no suggestion for shrinking the size of Musil's magnetron and displacing it to the side to the point where uniformity becomes a problem. Hence, there is no reason presented in the applied references to rotate an unbalanced magnetron.

A new dependent claim has been added to require the magnetron to be asymmetric about the target.

The Examiner has rejected Claim 10 under 35 USC §101 for same-type double patenting over Claim 7 of US Patent 6,290,825 (hereafter Fu-825). This claim has been amended to recite a greater degree of unbalance, as supported at page 18, line 18 and not claimed in Fu-825 so that only a question of obviousness-type double patenting remains.

The Examiner has rejected Claim 6 for obviousness-type double patenting over Claim 7

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of Fu-825. He has further rejected Claim 7-9 for obviousness-type double patenting over Claim 7 or possibly Claims 7-9 of Fu-825 in view of US Patent 5,650,652 to Eldelstein. He has yet further provisionally rejected Claims 6 and 7 for obviousness-type double patenting of co-pending Application 09/918,135 (hereafter Fu-135). A Terminal Disclaimer over Fu-825 and Fu-135 is submitted herewith. Therefore, these obviousness-type double patenting rejections should be removed.

Claim 6 has been broadened to remove the limitations of power levels and ionization densities. These limitations are added back in new dependent claims.

A new set of claims have been added to recite a more generic rotatable unbalanced magnetron.

In view of the above amendments and remarks, reconsideration and allowance of all claims are respectfully requested. If the Examiner believes that a telephone interview would be helpful, he is invited to contact the undersigned attorney at the listed telephone number, which is on California time.

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Serial No. 09/918,136

Version with markings to show changes made

In the specification:

Paragraph at page 1, lines 6-9:

This application is a division of Serial No. 09/546,798, filed April 11, 2001, now issued as US Patent 6,306,265 [issue fee paid], which is a continuation in part of Serial No. 09/373,097, filed August 12, 1999, now issued as US Patent 6,183,614, which is a continuation in part of Serial No. 09/249,468, filed February 12, 1999, now issued as US Patent 6,290,825, all of which are incorporated herein by reference in their entireties.

Paragraph at page 8, lines 3-5:

The invention also includes sputtering under conditions [with condition], such as a sufficiently high target power and high magnetic field away from the target, that a non-linear wave-beam interaction occurs that pumps energy into plasma electrons, thereby increasing the plasma density.

Paragraph at page 10, lines 2-8:

Although the two pole faces 62, 68 are illustrated with specific magnetic polarities producing magnetic fields extending generally perpendicularly to the plane of illustration, it is of course appreciated that the opposite set of magnetic polarities will produce the same general magnetic effects as far as the invention is concerned. The illustrated assembly produces a generally semi-toroidal magnetic field having parallel arcs extending perpendicularly to a closed path with a minimal field-free region in the center. There results a closed tunnel of magnetic field lines forming struts of the tunnel.

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Paragraph at page 13, line 25 t page 14, line 9:

A related shape is represented by a triangular magnetron 126, illustrated in plan view in FIG. 9. It has a triangular outer pole face 128 of one magnetic polarity surrounding a substantially solid inner pole face 130 of the other magnetic polarity with a gap 132 between them. The triangular shape of the inner pole face 130 with rounded corners allows hexagonal close packing of the button magnets 90, 92 of FIG. 6. The outer pole face 128 has three straight sections 134, which are preferably offset by 60° with respect to each other and are connected by rounded corners 136. Preferably, the rounded corners 136 have smaller lengths than the straight sections 134. One rounded corner 136 is located near the rotation center 78 and target center, preferably within 20%, more preferably within 10% of the target radius, and most preferably with the apex portion of the outer pole face 128 overlying the rotation center 78. The triangularly shaped inner pole piece 130 may include a central aperture, but it is preferred that the size of such an aperture be kept small to minimize the size of the central magnetic cusp.

Paragraph at page 16, lines 16-26:

The experimental work producing the process results presented below has demonstrated the advantage of a small magnetron area. If the triangular magnetron configuration of FIGS. 11 and 12 is adjusted to have significantly smaller apex angle θ with a reduced gap between the inner and outer poles, the total magnetic flux produced is limited by the permeability of the magnets. Therefore, as the apex angle and gap are decreased, the magnetic field across the gap does not extend so far away from the magnetron. As a result, the high-density plasma [does not] extends over an increasingly shallow height in front of the target. One approach to increase the effective magnetic flux is to use bar magnets instead of button magnets. The bar magnets have a larger fill factor in the pole area so that for a given total area and a maximum magnetic permeability (per unit area of magnet), a large magnet flux is produced.

Paragraph at page 21, lines 8-17:

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A series of experiments were performed using a triangular magnetron 210 illustrated in the plan view of FIG. 18 and the side view of FIG. 19 including a generally triangular outer pole 212 surrounding an inner pole 214 of the opposite magnetic polarity. The magnetron 210 is placed behind a 1.2cm-thick planar target [216] 14 of titanium sealed to the otherwise conventional sputter reactor of FIG. 1. However, the magnetron 210 is not rotated during the tests, and various probes 218 are inserted from the below with the probe tip located about 1cm below the target [216] 14 at a position between the magnetron poles 212, 214 at about two-thirds of the target radius. Typical chamber operating conditions used during the tests are an argon gas pressure of 1.6 milliTorr and 2kW of DC target power producing a target voltage of 455VDC.

Paragraph at page 24, line 18 to page 25, line 6:

The conditions permitting the launching of the lower hybrid mode and its parametric conversion to another mode capable of coupling to the thermalized electrons depend greatly on the magnetic configuration and strength associated with the magnetrons. The magnetrons and planar target described for this invention appear to satisfy the conditions. Other magnetrons have been tested with planar targets, but no plasma waves are observed. Apparently, the electron mirror configuration of the complexly shaped target of Matsuoka et al. fails to launch the lower hybrid mode, and they fail to report any wave lower than about 100MHz. In view of our experience and the apparent [apparently] phase velocity of the 22MHz mode, it seems necessary that a plasma mode be excited between 5 and 75MHz, preferably between 10 and 50MHz, in order to pump the 1 to 20eV plasma electrons. The launching of any plasma waves seems to depend upon a magnetic field projecting far away from the target. Matsuoka et al. accomplish this by a complex hollow cathode design. The present invention accomplishes this by the unbalanced magnetic field strengths of the two poles of the magnetron, which produces a vertical magnetic field far away from the target, as well as by driving the reactor at a high power level.

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Replace the claims with:

6. (Amended) A method of sputtering a material from a target comprising a metal onto a working substrate supported on a pedestal in a system including a magnetron disposed on a side of said target opposite said pedestal and including an outer pole of one magnetic polarity and surrounding an inner pole of another magnetic polarity, wherein said outer pole extends from a [said] enter of said target to a peripheral portion of said target and has an area smaller than a similarly extending circle, said method comprising:

rotating said magnetron about said [a] center of said target to achieve full sputtering coverage of said target; and

capacitively coupling power into said chamber at least partially by applying DC power to said target but not including inductively coupling power into said chamber to thereby excite said working gas into a plasma to sputter said metal from said target onto said working substrate [, an amount of said DC power being no more than 18kW normalized to a circular reference substrate of 200mm diameter, thereby achieving an ionization density of said metal of at least 20%].

10. (Amended) The method of Claim 6, wherein an integrated magnetic flux produced by said outer pole is at least 2.0 [1.5] times an integrated magnetic flux produced by said inner pole.

11. (Twice Amended) An tungsten fill process, comprising the steps of:

placing a substrate containing a hole formed in a dielectric layer in a magnetron sputter reactor including a titanium target and a magnetron comprising an inner pole of a first magnetic polarity and producing a first total magnetic flux and an outer pole of an opposite second magnetic polarity, producing a second total magnetic flux at least 1.5 times said first magnetic flux, and surrounding said first magnetic pole;

in said magnetron sputter reactor, sputtering a barrier layer of titanium and titanium

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nitride into said hole while rotating said magnetron about a center of said titanium target; and

thereafter filling tungsten into said hole of said substrate.

12. (Amended) The process of Claim 11, further comprising an [a rapid thermal] anneal of said substrate using radiant lamps and performed between said sputtering and filling steps.

17. (New) The process of Claim 16, wherein said magnetron is asymmetric about an axis about which said magnetron is rotated.

18. (New) The method of Claim 6, wherein an amount of said DC power is no more than 18kW normalized to a circular reference substrate of 200mm diameter.

19. (New) The method of Claim 6, wherein an amount of said DC power is sufficient to achieve an ionization density of said metal of at least 20%.

20. (New) The method of Claim 6, wherein said metal is a barrier metal.

21. (New) A method of sputtering a material from a target comprising a metal onto a working substrate supported on a pedestal in a system including a magnetron disposed on a side of said target opposite said pedestal and including an outer pole of one magnetic polarity and surrounding an inner pole of another magnetic polarity and being asymmetric about a center of said target, said method comprising:

rotating said magnetron about said center of said target to achieve full sputtering coverage of said target; and

capacitively coupling power into said chamber at least partially by applying DC power to said target and exciting said working gas into a plasma to sputter said metal from

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said target onto said working substrate .

22. (New) The method of Claim 21, wherein said magnetron has a generally triangular shape with an apex closer said center of said target than to a periphery thereof.

23. (New) The method of Claim 21, wherein an amount of DC power applied to said target is sufficient to achieve an ionization density of at least 20%.

24. (New) The method of Claim 23, wherein said metal is a barrier metal.

25. (New) The method of Claim 21, wherein said metal is a barrier metal.

26. (New) The method of Claim 21, wherein said working gas is excited into said plasma without inductively coupling power into said chamber.

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